View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by SJSU ScholarWorks

San Jose State University
SJSU ScholarWorks

Master's Theses | Master's Theses and Graduate Research

1996

The utility of diagramming cockpit preflight procedures

Michiko Ann Saylor
San Jose State University

Follow this and additional works at: https://scholarworks.sjsu.edu/etd_theses

Recommended Citation
Saylor, Michiko Ann, "The utility of diagramming cockpit preflight procedures" (1996). *Master's Theses*. 1261.
DOI: https://doi.org/10.31979/etd.wmg7-v7wg
https://scholarworks.sjsu.edu/etd_theses/1261

This Thesis is brought to you for free and open access by the Master's Theses and Graduate Research at SJSU ScholarWorks. It has been accepted for inclusion in Master's Theses by an authorized administrator of SJSU ScholarWorks. For more information, please contact scholarworks@sjsu.edu.

INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each original is also photographed in one exposure and is included in reduced form at the back of the book.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.

UMI

A Bell & Howell Information Company
300 North Zeeb Road, Ann Arbor MI 48106-1346 USA
313/761-4700 800/521-0600

THE UTILITY OF DIAGRAMMING COCKPIT PREFLIGHT PROCEDURES

A Thesis

Presented to

The Faculty of the Interdisciplinary Studies Program in Human Factors and Ergonomics

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Michiko Ann Saylor

May 1996

UMI Number: 1379376

Copyright 1996 by
Saylor, Michiko Ann

All rights reserved.

UMI Microform 1379376
Copyright 1996, by UMI Company. All rights reserved.

This microform edition is protected against unauthorized
copying under Title 17, United States Code.

UMI
300 North Zeeb Road
Ann Arbor, MI 48103

© 1996

Michiko Ann Saylor

ALL RIGHTS RESERVED

APPROVED FOR THE INTERDISCIPLINARY STUDIES PROGRAM IN HUMAN FACTORS AND ERGONOMICS

Dr. Elizabeth Zoltan

Dr. Louis E. Freund

Dr. Kevin Jordan

Mr. Dan Neal

APPROVED FOR THE UNIVERSITY

ABSTRACT

THE UTILITY OF DIAGRAMMING COCKPIT PREFLIGHT PROCEDURES

by Michiko Ann Saylor

An experiment was performed to test whether diagram aids decreased learning times of complex procedures. Forty-seven pilots (45 males, 2 females) learned one of four types of abbreviated cockpit preflight procedures using panels for B737-300, B727, B757, and DC-10 aircraft. The first two procedures were composed of sequentially ordered items; the next two procedures were composed of randomly ordered items. In both types of procedure conditions, half of the participants were also given a diagram to follow; the other half were not. Test hypotheses were: (a) learning times of sequentially-ordered procedures would be faster than randomly-ordered procedures; (b) learning times of procedures with patterns would be faster than procedures without patterns; and (c) there would be an interaction of order of items and pattern presence variables. Results indicated only the first hypothesis, that sequentially-ordered procedures would be faster to learn than randomly-ordered procedures, was supported.

ACKNOWLEDGMENTS

Special thanks go to Sue Nielsen and Dick Slinn, SFO Flight Managers, United Airlines, for their support of my endeavor, and to my thesis committee members Dr. Elizabeth Zoltan, Dr. Louis Freund, Dr. Kevin Jordan, and Mr. Dan Neal for their professional and academic wisdom. Additionally, Dave Saylor deserves an award for knowing when to lend a shoulder and when to steer clear.

Correspondence concerning this thesis should be addressed to P. O. Box 1115, Santa Clara, CA 95052-1115.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

The Utility of Diagramming Cockpit Preflight Procedures

Michiko Ann Saylor

San Jose State University

Abstract

An experiment was performed to test whether diagram aids decreased learning times of complex procedures. Forty-seven pilots (45 males, 2 females) learned one of four types of abbreviated cockpit preflight procedures using panels for B737-300, B727, B757, and DC-10 aircraft. The first two procedures were composed of sequentially ordered items; the next two procedures were composed of randomly ordered items. In both types of procedure conditions half of the participants were also given a diagram to follow; the other half were not. Test hypotheses were: (a) learning times of sequentially ordered procedures would be faster than randomly ordered procedures; (b) learning times of procedures with patterns would be faster than procedures without patterns; and (c) there would be an interaction of order of items and pattern presence variables. Results indicated only the first hypothesis, that sequentially ordered procedures would be faster to learn than randomly ordered procedures, was supported.

The Utility of Diagramming Cockpit Preflight Procedures

Throughout the careers of most professional pilots are periods in which they must receive training on an aircraft that is new to them. Depending on the type of aircraft, crewmember position, and corporate or military policies, the training period can range from a few days to several weeks. In general, the larger the aircraft, the longer the training period. Much of the increase in training time is due to an increase in the complexity of systems and procedures. Sometimes the pilots are paid to learn in classroom sessions; sometimes they are expected to learn most of the information during their own free time at home. For organizational and individual reasons, it would benefit all to shorten the amount of time needed to learn systems and procedures, thereby increasing training efficiency. There are several systems and procedures areas that could possibly be improved: systems information, systems and aircraft limitations, cockpit and exterior preflight procedures, emergency procedures, and flight techniques. This study focuses on decreasing the amount of time needed to learn cockpit preflight procedures of large commercial aircraft.

Part of every pilot's duties before embarking on a flight includes checking and setting up systems and instruments in the cockpit, otherwise known as the cockpit preflight procedure. The procedure is fairly simple in a small aircraft and easily learned. However, as the size of the aircraft grows, complexity of the systems increases as does the length of the preflight procedure. A pilot may have to memorize up to 100 items in a procedure, which is not an impossible task, but the time needed to learn the procedure can be quite lengthy. Decreasing the learning time of cockpit preflight procedures can contribute to increasing the overall training efficiency of aircraft training programs.

Training Efficiency

Wickens (1992) defines training efficiency as "the greatest level of proficiency per dollar invested" (p. 231). It is heavily dependent on how information is presented to allow people to learn in the shortest amount of time and retain the information. Langley and Simon (1981) offer several methods of modifying components of the human information processing system to enhance learning. To summarize, these methods are: (a) adding to or reorganizing the knowledge base; (b) augmenting the recognition mechanism; (c) augmenting search strategies; (d) modifying evaluation functions; (e) augmenting short-term memory capacity; (f) augmenting lexical, syntactic, and semantic knowledge; and (g) enriching information representations. To enhance learning of cockpit preflight procedures, methods (e) and (g) seem most appropriate and are discussed in the next few paragraphs.

Augmenting short-term memory. Method (e), augmentation of short-term memory capacity, is generally linked to Miller's (1956) influential research on memory span. This research indicates that humans have the short-term memory capacity to remember 7 +/-2 items or chunks of information. His research has been replicated many times and enhanced over the decades. Chase and Ericsson (1981) found that working capacity of short-term memory is closer to the order of three to four units, also confirmed by Langley and Simon (1981). Wickens (1992) lists practical applications of chunking information such as improving computer programming, decision making, chess playing, air traffic control communications, and memory for phone numbers. The list of applications can easily be extended to include improvement of cockpit preflight procedures since the items in the procedures lend themselves to being grouped into chunks.

Enriching information. Method (g), enriching information representations, can be accomplished in several ways including employing mnemonic devices, observing information in an event, providing worked examples, associating information with odor, and providing a diagram or pattern of the information. Higbee, Clawson, Delano, and Campbell (1990) showed mnemonics increased recall of lists of errands. Mnemonics could also aid memory of lists of items in a cockpit preflight procedure. Experiments by Howard Jr., Mutter, and Howard (1992) showed that when participants were allowed to observe a demonstration of the reaction-time tasks they were to perform, these participants subsequently performed better than participants not given the demonstration. Demonstrating a cockpit preflight procedure to a pilot could facilitate learning of the procedure and some airlines do employ this method. A study by Sweller, Chandler, Tierney, and Cooper (1990) demonstrated the superiority of providing worked examples in facilitating the learning of math formulas, but worked examples would not be practical for learning all types of procedures. Schab's (1990) study demonstrated that specific odors could trigger long-term memory recall. This method would be impractical for learning cockpit preflight procedures due to the large number of memory items in the procedures and the limited capability of the human olfactory system.

As for diagramming information, three previous studies show the strength of this form of information enrichment. Taylor and Tversky (1992) performed an experiment which tested memory of maps. One of their conclusions was that humans have excellent memories for maps. In 1968, Brooks performed a series of experiments indicating that "verbal and spatial information are handled in distinct modality-specific manners" (p. 349). He showed that people are capable of concurrently handling two different types of the same information, such as a map and related verbal text. Similarly, Paivio's (1986) dual code theory (DCT) is a result of many years of work and refinements starting in the early 1970's. According to Paivio, there are two separate classes of information processing, verbal and nonverbal symbolic subsystems, neither of which needs to be consciously attended to process information. These subsystems are each further broken down into visual, auditory, and tactile levels. When information is simultaneously presented to each of the different subsystems, memory is enhanced; when information is simultaneously presented to different levels within the same subsystem, memory is unaffected or degraded. Research further shows that memory recall is also enhanced when a task is presented to one subsystem and a response is required using the other subsystem.

The research of both Brooks and Paivio strongly suggests that diagramming textual information of a cockpit preflight procedure would present information to both verbal and nonverbal (or spatial) subsystems. Their research is confirmed by several studies. Stopher and Kirsner (1981) found that reaction times to a picture with a shared-concept sentence were faster than reaction times to a picture with a unique-concept sentence. Their study demonstrated performance was better between similar information presented to two different subsystems than different information presented to two different subsystems. In 1988, Smyth, Pearson, and Pendleton found that a movement-suppression task did not affect memory for visually presented words or spatial positions. Their results demonstrated that a task using a nonverbal subsystem did not affect visual memory within the same subsystem. Koriat, Ben-Zur, and Nussbaum (1990) found that memory of a procedure for tasks that would be performed was better than memory of a procedure for tasks that would be recalled. Their finding showed that recall is better when a response is required using a different subsystem rather than the same subsystem to which the task was originally presented. Peterson, Kulhavy, Stock, and Pridemore (1991) performed a study in which participants were either given landmark maps or boundary maps, then given a story to read pertaining to the maps. During recall sessions of the text, participants who used landmark maps had better recall than participants who used boundary maps. As in the Stopher and Kirsner study, the Peterson et. al. study demonstrated participants had better performance when similar information was presented to two different subsystems rather than when different information was presented to two different subsystems. The landmark maps were similar to the text, whereas the boundary maps which were simple outlines were different from the text. A follow-up study by Kulhavy, Stock, Peterson, Pridemore, and Klein (1992) refined and confirmed the Peterson et al. study, again showing that participants had better recall when similar information was presented to two different subsystems rather than when different information was presented to two different subsystems.

Two 1992 studies by Hodes and by Glenberg and Langston most directly demonstrate how useful it is to pair text with diagrams. Hodes examined whether providing a visual diagram or written instructions to form mental images would produce better recall of physiology information. She found that participants recalled more information when given the visual diagram than when given the written instructions. Glenberg and Langston performed a study in which participants were given a four-step procedure to learn. Some procedures contained a picture of the procedure; other procedures contained no picture. Results showed that fewer procedural errors were made by participants when they were provided a picture of the procedure.

Summary of Options

In summary, of all the possible options to decrease the amount of time needed to learn cockpit preflight procedures of large commercial aircraft, the most practical options are to either chunk items within the procedure, employ some type of associated mnemonic system, have pilots observe an instructor performing the procedure, or provide a diagram of the procedure along with the text. The purpose of this study is to examine the benefits derived from diagramming procedures for three reasons: (1) pilots may be better at learning visually, rather than verbally, presented information (Wickens, 1992); (2) cockpit preflight procedures are primarily spatial tasks and diagrams are a spatial form of information; and (3) diagrams with textual procedures would present information to both verbal and nonverbal/spatial cognitive channels (Paivio, 1986).

Previous Study

A preliminary study was performed to examine whether adding a pattern to cockpit preflight procedures decreases the amount of time needed to memorize the procedures, and thus, increases training efficiency (Saylor, 1995). Two independent variables were manipulated, the most important one being presence of pattern. Two levels were set for this variable: pattern and no pattern. The other variable, type of transfer, was a control variable with two levels: positive items and negative items. Positive transfer items were defined as similar items requiring the same actions between different procedures, while negative transfer items were defined as similar items requiring different actions between different procedures. Four sets of cockpit procedures for three types of aircraft were created, each with eight items to memorize. The first two sets were composed of positive transfer items, with and without a pattern of the items. The second two sets were composed of negative transfer items, with and without a pattern of the items. In manipulating the two independent variables, three hypotheses were tested: (a) learning times for patterned preflight procedures would be faster than learning times for non-patterned procedures; (b) learning times for positive transfer items would be faster than learning times for negative transfer items; and (c) there would be no interaction between the factors of pattern presence and type of transfer. Sixteen aviation students participated in the study, four in each one of the four possible conditions.

Results of the Saylor (1995) study did not support the conclusion that diagramming cockpit preflight procedures decreases learning time of the procedures. However, it was noted in the study that diagrammed procedures could still improve training efficiency for two reasons. First, the study may have lacked sufficient realism. The length of the experimental procedures was quite short. Whereas typical procedures may contain as many as 20 items on one page of a procedure, this study only required participants to learn a total of eight items per procedure. Under the experimental conditions of the study, having many items on one page could also have caused a corresponding pattern to be quite complex. Realism was also reduced in that students learned each of the three aircraft procedures in a consecutive manner with only a five minute break between procedures. Under actual operations a pilot may have up to several years between learning new procedures. A second limitation of the pilot study was that sample size was quite small. Four sets of scores were eliminated for various reasons leaving only three sets of scores in each of the four test conditions. Based on these two reasons, the benefits of decreased procedural learning time may still outweigh the costs of adding a pattern, and cockpit training efficiency may still be improved.

Continued Effort

The present study was undertaken to further the efforts of the previous study by performing a similar experiment with the following enhancements. First, the type of transfer variable was eliminated because it did not show interaction with the pattern variable. It was replaced with another control variable, order of items. Mandler (1977) and Taylor and Tversky (1992) suggest that memory is adversely affected if information is not presented in a logical, hierarchical manner. If items in a procedure are arranged such that the order in which they flow around the cockpit is random, they should be more difficult to learn than if they are arranged in a sequential order. Second, the number of memory items in a procedure was increased to 18 items. This increase more than doubled the number of items that could easily be processed according to Miller's memory span (Miller, 1956). The items were also limited to 18 items to keep the experimental session length manageable. Third, procedures were created for four different aircraft, which supplied data for three trials rather than two trials after a practice session. Fourth, participants learned no more than one procedure per day. This expanded time frame helped to mirror the fact that a pilot does not usually learn one aircraft's procedure immediately after learning another aircraft's procedure. It also kept data collection to a reasonable time frame and reduced proactive and retroactive memory interference. And fifth, the sample size was increased to a minimum of 40, or ten per condition.

With the five enhancements over the previous study, this study was intended to provide more realistic results as to whether or not diagrammed preflight procedures can improve training efficiency. There were three test hypotheses: (a) learning times will be faster for preflight procedures with diagrams than procedures without diagrams; (b) learning times will be faster for sequentially ordered preflight procedures than randomly ordered procedures; and (c) there will be an interaction between the factors of diagram presence and order of items (i.e., diagram presence would affect sequentially ordered procedures but not randomly ordered procedures).

Method

Participants

Forty-five male and two female participants were recruited from the San Jose State University (SJSU) Aviation Department, the Foothill College instrument flying course, Reid-Hillview Airport, San Jose International Airport, and Palo Alto Airport. All participants had flown an aircraft or flight simulator within the preceding six months, and all but three possessed a minimum of a private pilot license. These three participants were student pilots, but possessed adequate levels of experience: Two were close to receiving a private license and one was completing the flight engineering course at SJSU. To balance experience levels among the four experimental conditions, the participants were grouped into one of four categories: (a) student pilot, (b) pilot with less than 100 flight hours, (c) pilot with 100 to 500 flight hours, and (d) pilot with more than 500 flight hours. No monetary compensation was given to the participants, but all were entered in a raffle in which four of them would be selected to receive free jet simulator time.

Materials

Materials for this experiment consisted of fold-out cockpit panels for B737-300, B727, B757, and DC-10 aircraft, two cockpit preflight procedures for each of the aircraft, diagrams for each of the procedures, scratch paper, and survey sheets. The fold-out panels, donated by United Airlines, provided pictorial representations of each of the different cockpits. There were three panels for each cockpit, one representing the overhead panel above the pilots' heads, one representing the forward instrument panel in front of the control wheels, and one representing the pedestal panel between the pilot seats. Four different types of cockpit preflight procedures were fabricated for all of the aircraft, with each of the procedures containing 18 check items. Each check item was also labeled with a number corresponding to a number on one of the fold-out panels for easy identification of the item (see Appendix A). The first type of procedure contained one text page with check items in a sequential order. The second type contained the same text page preceded by a page containing a diagram of the sequentially ordered items. The third type of procedure contained one text page with the same check items as the first type but in a random sequence. The fourth type contained the same text page as the third type preceded by a page containing a diagram of the randomly sequenced items. The sequence of items was varied from aircraft to aircraft in the sequentially ordered procedures causing the corresponding patterns to be different.

A one-page survey sheet with three questions was created to query participants about the usefulness of the diagrams. The first question asked if a participant understood the layout of the diagrams. The second question asked how helpful the diagrams were. The third question asked how frequently the diagrams were used. The survey is shown in Appendix B.

Design

The experiment was a 2 x 2, between-subjects factorial design, with the first variable being presence of diagram and the second variable being order of items. The first condition was diagram present/logical sequence, the second condition was diagram absent/logical sequence, the third condition was diagram present/random sequence, and the fourth condition was diagram absent/random sequence. Aircraft type was not included as a third variable and the sequence of aircraft was varied within the trials. Participants were categorized according to flight experience and then randomly assigned to one of the four conditions. Each participant provided three scores, one score for three different aircraft after an initial practice trial. The dependent measure was time to complete a trial.

Procedure

Fold-out panels for one of the aircraft were mounted to the wall and table in a small private room located in Dudley Moorhead Hall at San Jose State University. With the table pushed against the wall, the pedestal panel was mounted to the right edge of the table, the instrument panel was mounted to the wall centered above the pedestal panel, and the overhead panel was mounted to the wall centered above the instrument panel. A stack of scratch paper was placed on the table to the left of the panels.

Each participant was instructed to sit to the right of the panels as though sitting in the First Officer's seat in the cockpit, however some participants preferred to sit directly in front of the panels. After reading the instructions, the participant was given an oral summary of the instructions and then handed the appropriate preflight procedure face down for the condition to which he or she had been assigned. When ready to begin, the participant turned the procedure over, the timer was started in his or her presence, and the participant was then left alone in the room with the door shut to learn the procedure in privacy. As per the instructions, the participant was to learn the textual procedure in the order presented, top-to-bottom and left-to-right (refer to sample procedures in Appendix A). Writing notes on the procedure or scratch paper was allowed, but no marks were allowed on the fold-out panels. The timer was paused anytime the participant had a question or problem with the procedure. Once the participant indicated that he or she had committed the procedure to memory the timer was again paused.

When ready to demonstrate the procedure, timing was restarted and the participant was required to perform each check in the procedure in the correct order. The participant was not required to name the items being checked but to simply touch the items while narrating what the actions were. For example, in the B757 procedures, a participant was to turn on the right electrical hydraulic pump and look for the associated pressure light to go off. He or she could touch the button and announce "push this button and look for that light to go out." If an error was made the participant was corrected and the demonstration restarted from the beginning. Errors involving lack of knowledge about specific aircraft systems were not considered errors if the participant performed logical checks. Continuing the example above, if the participant pointed to the "SYS PRESS" light above the hydraulic panel and indicated that particular light should be off instead of the "PRESS" light associated with the button, this was considered a logical action based upon the participant's knowledge. Timing stopped once the participant demonstrated the entire procedure with no errors and he or she was dismissed for the day.

The first day's trial was treated as a practice trial to familiarize each participant with the experimental procedure. Each participant then returned for three more days, learning one procedure per day of the remaining aircraft. No less than 12 hours or one night's sleep and no more than one day or two nights' sleep lapsed between procedures. Following completion of the last procedure, those participants in the conditions where a diagram was present were given the survey to complete.

Results

Scores from seven male participants were eliminated for various reasons. The first four were due to a problem found in the initial procedures. Although all procedures contained the same number of primary items to memorize, the number of secondary memory items associated with each of the primary items was not the same across aircraft. An example of a primary item would be to turn on the window heat. A secondary item would be to then verify the green "on" lights came on, or the amber "inop" lights went off, or both. Three more sets of scores were eliminated due to an experimenter error of giving one participant a wrong procedure on the last day, a participant's self-admitted learning disability which resulted in his inability to follow instructions on the first day, and a participant's personal time constraint which appeared to adversely affect his performance on three of his four days. Of the participant scores that were eliminated, three were in the diagram absent/random order condition, three were in the diagram absent/sequential order condition, and one was in the diagram present/sequential order condition. A total of 40 participant scores were included in the data analyses, ten in each condition.

Table 1 shows the average scores for each of the combinations of the independent variables. A two-between, one-within analysis of variance was performed on the effects of diagram presence, order of items, and trial sequence. No significant effects were found for diagram presence, $F(1,108) = 0.31$, $p > .05$, trial number, $F(2,108) = 0.31$, $p > .05$, and any of the interactions, $F(1,108) = 1.65$, $p > .05$, $F(2,108) = 0.23$, $p > .05$, $F(2,108) = 0.34$, $p > .05$, $F(2,108) = 0.06$, $p > .05$. A significant effect was found for order of items, $F(1, 108) = 121.60$, $p < .05$. On average, participants using the sequentially ordered

Table 1. Average Learning Times (min) of Cockpit Procedures

		Diagram		No diagram	
Order of items	Aircraft trial	M	SD	M	SD
Sequential	1	21.33	7.70	23.89	6.41
	2	18.19	5.37	21.39	3.89
	3	19.97	8.58	21.50	7.02
	All	19.83	7.31	22.26	5.88
Random	1	37.40	8.04	35.40	7.83
	2	35.51	6.68	36.29	8.13
	3	35.39	4.77	33.71	10.10
	All	36.10	6.11	35.13	7.41

procedures learned their procedures 1.7 times faster than did the participants who used the randomly ordered procedures (Ms = 21.05, 35.62, respectively). Figure 1 provides a graph of the average scores.

During the experimental trials, many of the participants learning the sequentially ordered procedures commented that the DC-10 procedures seemed especially easy to learn. Because of the numerous comments, additional analyses were performed on the DC-10 times. Results did show the DC-10 procedure produced significantly faster learning times in the diagram absent/sequential order condition when compared to the other three aircraft, $t(13) = 3.19$, $p < .05$, $t(14) = 3.09$, $p < .05$, $t(13) = 1.87$, $p < .05$.

Table 2 presents a breakdown of participant responses to the survey form (see Appendix B). Scale marks were averaged for each participant's data trials, excluding the practice trial. The helpfulness scale was divided into three levels: "high" for marks that averaged in the right third of the scale, "medium" for marks that averaged in the middle third of the scale, and "low" for marks that averaged in the left third of the scale. The frequency of use scale was divided into four levels: "high" for marks that averaged in the right third of the scale, "medium" for marks that averaged in the middle third of the scale, "low" for marks that averaged in the left third of the scale, and "none" for marks that averaged at the extreme left of the scale.

In general, participants favored the use of diagrams with the procedures, even some of the participants in the random order group. A chi-square analysis was performed to analyze the survey data. Responses in the sequential and random order groups were tallied between two categories, helpful or not helpful. Participants who indicated diagrams were of high or medium helpfulness were tallied in the helpful category, with the remaining ones being tallied in the not helpful category. The participant in the sequential order group who indicated he did not use the diagrams may have misunderstood the

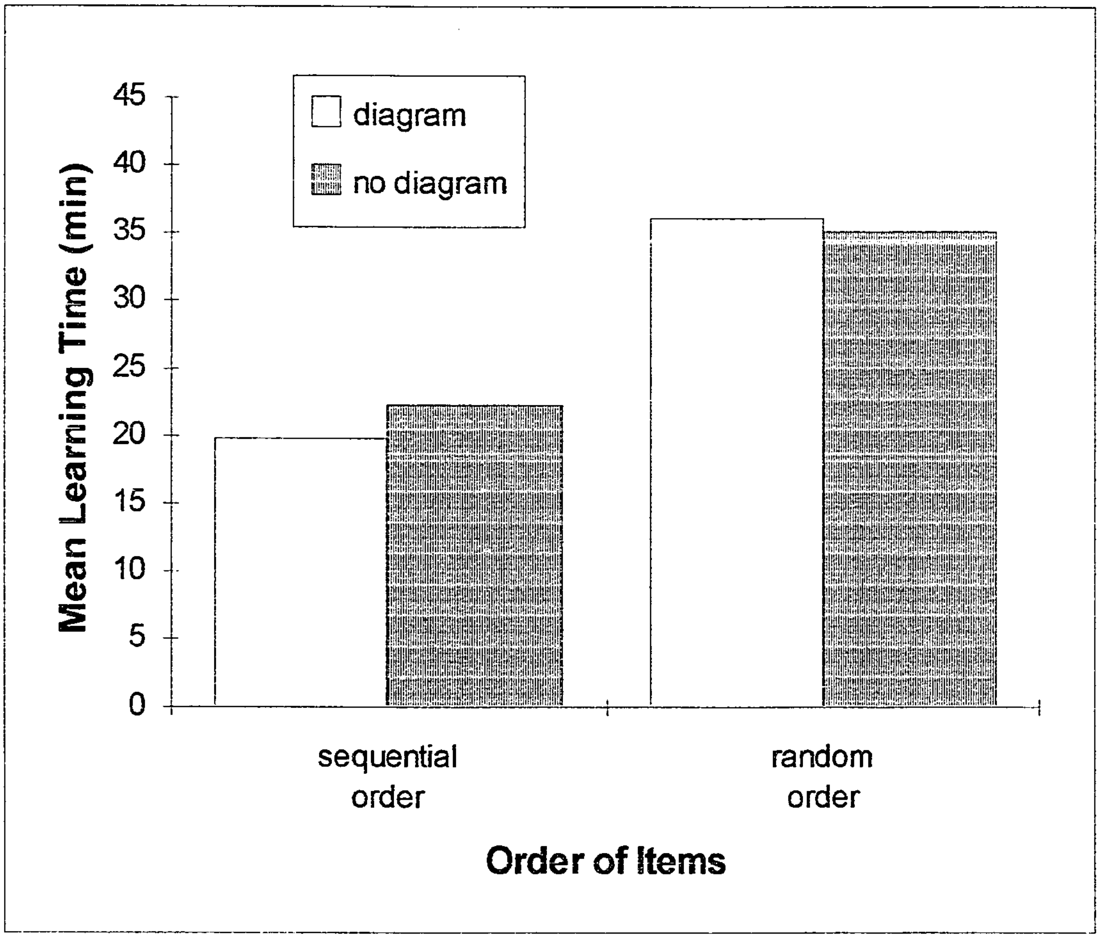

Figure 1. Graphical depiction of the mean learning times as a function of item order within conditions.

Table 2. Results of Participant Surveys

		Use frequency			
Level of helpfulness	No.	High	Medium	Low	None
Sequential-order group					
High	7	2	5		
Medium	3		2		1
Random-order group					
High	1	1			
Medium	3		3		
Low	6			2	4

survey form. Even though he indicated a medium level of helpfulness, his survey response was conservatively tallied in the not helpful category. The chi-square results showed diagrams were considered helpful, $\chi^2(1) = 3.52$, $p < .05$.

Discussion

As shown by the data analyses, the null hypothesis that sequentially ordered procedures can be learned no faster than randomly ordered procedures can be rejected with reasonable certainty. This result supports the Mandler (1977) and Taylor and Tversky (1992) studies, indicating memory is indeed adversely affected if information is not presented in a logical, hierarchical manner. It is interesting to note that in the diagram absent/sequential order condition the DC-10 procedure stood out as an additional factor. This could not have been due to the aircraft itself or its particular fold-out panels because the DC-10 was not a significant factor in the other conditions. Upon closer examination of the aircraft's procedure it is noticed that the serendipitous sequence with which the items were ordered was of a fairly rhythmic back-and-forth, top-to-bottom sequence. This sequence further supports the Mandler and the Taylor and Tversky studies.

Data analyses further indicated the remaining two null hypotheses cannot be rejected. Diagram presence did not improve procedural learning time and there was no interaction between the factors of diagram presence and order of items. Even with the enhancements over the previous study, this study's results of the diagram effect were nearly identical to the results of the previous Saylor (1995) study.

By all indications of previous research (Brooks, 1968; Glenberg & Langston, 1992; Hodes, 1992; Koriat et al., 1990; Kulhavy et al., 1992; Paivio, 1986; Peterson et al., 1991; Smyth et al., 1988; Stopher & Kirsner, 1981; Taylor & Tversky, 1992), the inclusion of diagrams with preflight procedures should have significantly improved learning times by pairing nonverbal or spatial information with related verbal information.

Results of this study with regard to diagram presence were puzzling; however, there is at least one possible explanation for the conflicting results. Nearly all of the previous studies measured performance by amount of recall or number of recall errors. Their main objectives were to measure memory retention. This study's emphasis was to find a method to decrease procedural learning time and increase training efficiency. Performance was measured by time rather than quantity or accuracy of recall. The different dependent measures between this study and the other studies may not be comparable.

Conclusion and Recommendations

The main purpose of this study was to focus on a method to decrease procedural learning time, not to study amount of memory retention. Since adding diagrams to preflight procedures did not produce significant decreases in learning times, studies should continue to examine whether chunking, mnemonics, procedure demonstration, or a combination of these methods will decrease learning times of the procedures. It may also be useful to examine these methods in combination with diagrams judging by the positive participant feedback of this study. Additionally, the evidence in this study should not be used to disprove previous research of the usefulness of pairing text with pictures. Dependent measures must first be equalized before comparing this study to the others.

References

Brooks, L. R. (1968). Spatial and verbal components of the act of recall. Canadian Journal of Psychology, 22(5), 349-368.

Chase, W. G., & Ericsson, K. A. (1981). Skilled memory. In J. R. Anderson (Ed.), Cognitive skills and their acquisition (pp. 141-189). Hillsdale, NJ: Erlbaum.

Glenberg, A. M. & Langston, W. E. (1992). Comprehension of illustrated text: Pictures help to build mental models. Journal of memory and language, 31, 129-151.

Higbee, K. L., Clawson, C., Delano, L., & Campbell, S. (1990). Using the link mnemonic to remember errands. The Psychological Record, 40, 429-436.

Hodes, C. L. (1992). The effectiveness of mental imagery and visual illustrations: A comparison of two instructional variables. Journal of Research and Development in Education, 26(1), 46-56.

Howard, J. H., Jr., Mutter, S. A., & Howard, D. V. (1992). Serial pattern learning by event observation. Journal of Experimental Psychology: Learning, Memory, and Cognition, 18(5), 1029-1039.

Koriat, A., Ben-Zur, H., & Nussbaum, A. (1990). Encoding information for future action: Memory for to-be-performed tasks versus memory for to-be-recalled tasks. Memory & Cognition, 18(6), 568-578.

Kulhavy, R. W., Stock, W. A., Peterson, S. E., Pridemore, D. R., & Klein, J. D. (1992). Using maps to retrieve text: A test of conjoint retention. Contemporary Educational Psychology, 17, 56-70.

Langley, P., & Simon, H. A. (1981). The central role of learning in cognition. In J. R. Anderson (Ed.), Cognitive skills and their acquisition (pp. 361-380). Hillsdale, NJ: Erlbaum.

Mandler, G. (1977). Organization and memory. In G. Bower (Ed.), Human memory (pp. 297-354). New York: Academic Press.

Miller, G. A. (1956). The magical number seven plus or minus two: Some limits on our capacity for processing information. Psychological Review, 63, 81-97.

Paivio, A. (1986). Mental representations: A dual coding approach. New York: Oxford University Press.

Peterson, S. E., Kulhavy, R. W., Stock, W. A., & Pridemore, D. R. (1991). How map features cue associated verbal content. Bulletin of the Psychonomic Society, 29(2), 158-160.

Saylor, M. A. (1995). Improving cockpit training efficiency through the use of patterned preflight procedures. Unpublished manuscript, San Jose State University, California.

Schab, F. R. (1990). Odors and the remembrance of things past. Journal of Experimental Psychology: Learning, Memory, and Cognition, 16(4), 648-655.

Smyth, M. M., Pearson, N. A., & Pendleton, L. R. (1988). Movement and working memory: Patterns and positions in space. The Quarterly Journal of Experimental Psychology, 40A(3), 497-514.

Stopher, K. & Kirsner, K. (1981). Long-term memory for pictures and sentences. Memory & Cognition, 9(1), 34-40.

Sweller, J., Chandler, P., Tierney, P., & Cooper, M. (1990). Cognitive load as a factor in the structuring of technical material. Journal of Experimental Psychology: General, 119(2), 176-192.

Taylor, H. A. & Tversky, B. (1992). Descriptions and depictions of environments. Memory & Cognition, 20(5), 483-496.

Wickens, C. D. (1992). Engineering psychology and human performance (2nd ed.). New York: HarperCollins.

Appendix A. Samples of Procedures

B737

25 STAB TRIM OVERRIDE SWITCH .... NORM

24 FIRE WARNING SYSTEM .... TEST
Hold TEST switch to OVHT/FIRE, observe ENG 1, APU, ENG 2, and WHEEL WELL fire handle lights come on, and bell sounds.

23 SPEED BRAKE LEVER .... DOWN

21 HYDRAULIC QUANTITY.................. CHECK
Check quantity above the RFL line.

22 VERTICAL SPEED INDICATOR ....ZERO
Verify zero fpm.

20 AIRSPEED INDICATOR .... CHECK
Verify digital airspeed readout indicates 45 ± 1 knot.

15 WING-BODY OVERHEAT ....TEST
Push the OVHT TEST button and check that the WING-BODY OVERHEAT lights come on after 5 seconds.

14 DUCT OVERHEAT LIGHTS................... OFF

10 WINDOW HEAT SWITCHES.................. ON

13 STALL WARNING.................................TEST
Push button No. 1, verify the Captain's stick shaker activates. Push button No. 2, verify the First Officer's stick shaker activates.

7 SERVICE INTERPHONE SWITCH ....OFF

5 TR 1, 2, AND 3..................................CHECK
Move selector to each position, check DC VOLTS at 20 ± 5 and DC AMPS at 0 ± 15.

1 YAW DAMPER SWITCH .... ON
Verify the YAW DAMPER light is off.

2 EFI and IRS SWITCHES ....NORMAL

3 FUEL PUMPS.. ON

17 FUEL QUANTITY ....TEST
Push and release the QTY TEST button, verify fuel indicators decrease and return to their original indication.

18 ENGINE OIL QUANTITY ....TEST
19 Push ENG OIL QTY TEST button and verify oil quantity pointers move toward zero, then return to original position when button is released.

19 ANTISKID SWITCH................................. ON
Verify ANTISKID INOP light off.

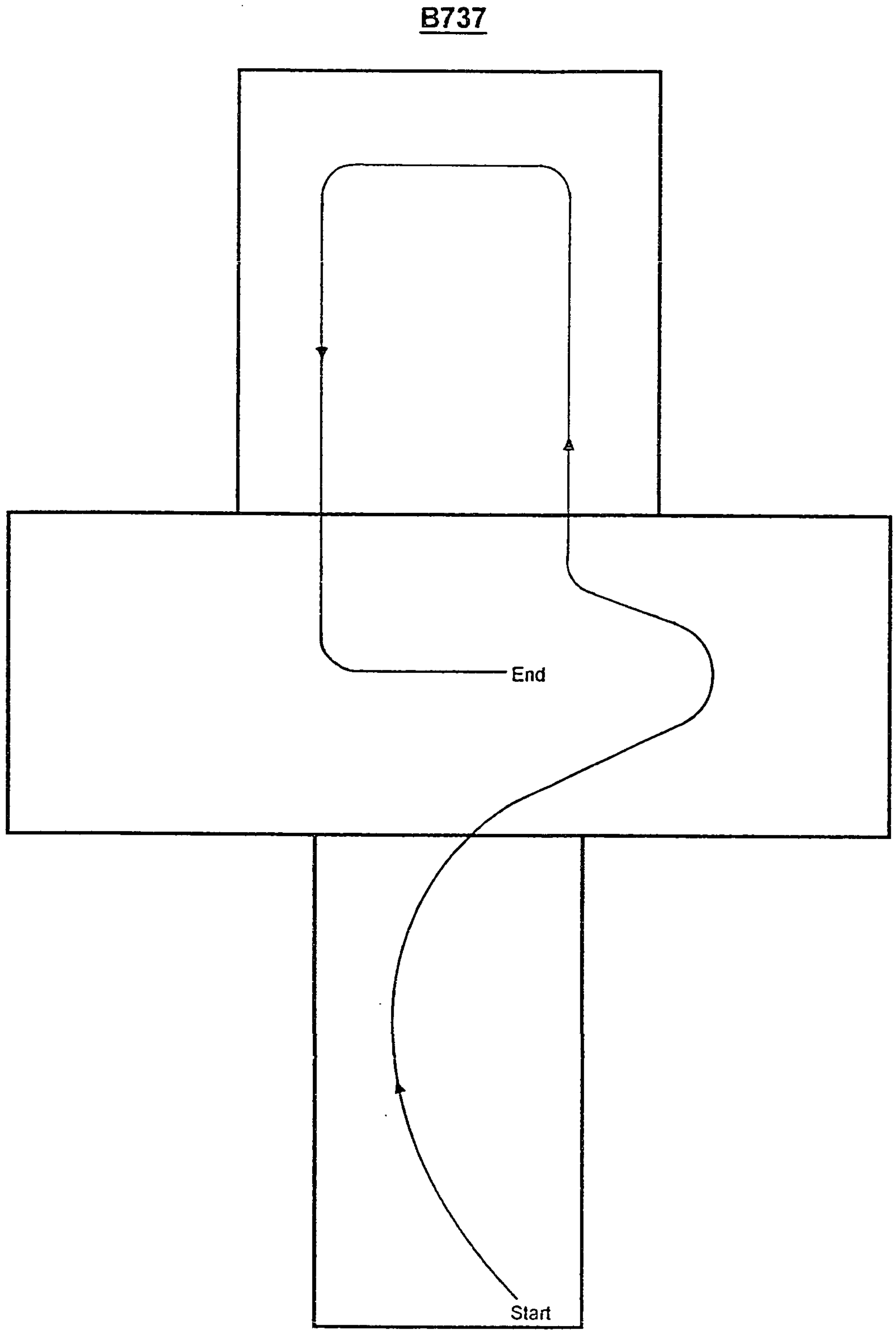

Diagram of the procedure.

B737

15 WING-BODY OVERHEAT .... TEST
Push the OVHT TEST button and check that the WING-BODY OVERHEAT lights come on after 5 seconds.

5 TR 1, 2, AND 3 ....CHECK
Move selector to each position, check DC VOLTS at 20 ± 5 and DC AMPS at 0 ± 15.

21 HYDRAULIC QUANTITY..................CHECK
Check quantity above the RFL line.

24 FIRE WARNING SYSTEM .... TEST
Hold TEST switch to OVHT/FIRE, observe ENG 1, APU, ENG 2, and WHEEL WELL fire handle lights come on, and bell sounds.

2 EFI and IRS SWITCHES............... NORMAL

17 FUEL QUANTITY................................ TEST
Push and release the QTY TEST button, verify fuel indicators decrease and return to their original indication.

10 WINDOW HEAT SWITCHES................. ON

3 FUEL PUMPS.. ON

7 SERVICE INTERPHONE SWITCH ....OFF

14 DUCT OVERHEAT LIGHTS .... OFF

25 STAB TRIM OVERRIDE SWITCH .... NORM

13 STALL WARNING...............................TEST
Push button No. 1, verify the Captain's stick shaker activates. Push button No. 2, verify the First Officer's stick shaker activates.

20 AIRSPEED INDICATOR.................. CHECK
Verify digital airspeed readout indicates 45 ± 1 knot.

18 ENGINE OIL QUANTITY.....................TEST
19 Push ENG OIL QTY TEST button and verify oil quantity pointers move toward zero, then return to original position when button is released.

22 VERTICAL SPEED INDICATOR.........ZERO
Verify zero fpm.

1 YAW DAMPER SWITCH........................ ON
Verify the YAW DAMPER light is off.

23 SPEED BRAKE LEVER.................... DOWN

19 ANTISKID SWITCH .... ON
Verify ANTISKID INOP light off.

B737

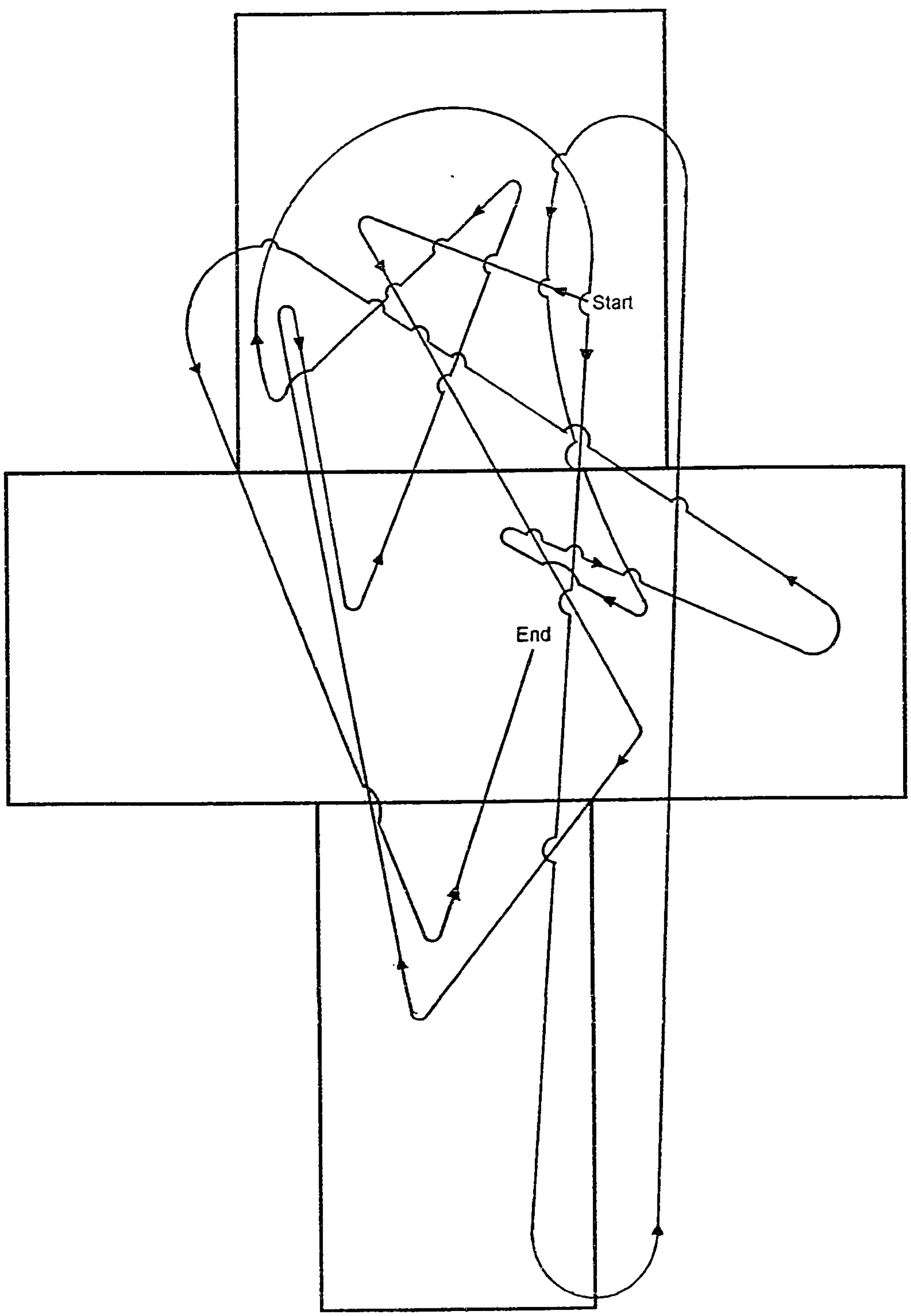

Diagram of the procedure

B727

18 RADIO ALTIMETER............................TEST
Push the TEST button and observe the warning flag appears.

17 ATTITUDE DIRECTOR
INDICATOR ....TEST
Push the PRESS TO TEST button on the ADI and observe a smooth movement into a climbing right turn indication (approximately 10° pitch up and 20° right roll).

15 LOW OIL PRESSURE LIGHTS.............. ON

14 PNEUMATIC BRAKE
HANDLE............................SAFETIED, OFF

13 MACH AIRSPEED WARNING.............TEST
Position TEST switch to No. 1 then to No. 2 and verify that the aural overspeed warning clacker sounds in each position.

12 FIRE WARNING.................................TEST
Hold FIRE TEST switch to ENGS & W.W. (maximum 30 seconds) and observe:

- Wheel well fire warning light come on.
- Engine fire warning lights come on.

11 PITOT STATIC HEAT .... ON
Position PITOT STATIC HEAT switches to ON and observe PITOT OFF light go off.

8 VOICE RECORDER............................TEST
Push the TEST button momentarily (about 1/2 second). After a short delay, observe two distinct deflections of the monitor meter pointer into the white area.

5 EMERGENCY EXIT
LIGHTS SWITCH..........GUARDED/ARMED

3 MAIN GEAR ANTISKID SWITCH......... OFF
Antiskid INOP lights on.

2 FLIGHT CONTROL WARNING
TEST SWITCH............................ TAKEOFF
Verify that warning horn sounds.

9 WINDOW HEAT SWITCHES................. ON
Verify green ON lights come on.

6 START VALVE ARMING
SWITCH .... GUARDED, OFF

4 GND PROX FLAP SYS INHIBIT
SWITCH .... GUARDED, SAFETIED

22 RUDDER TRIM..................................ZERO

21 AUTOPILOT AIL AND ELEV
SWITCHES.......................... DISENGAGED

20 FLAPS ....UP
15 Check position indicators and flap handle in agreement.

19 ALTITUDE ALERT ....NO FLAG

B727

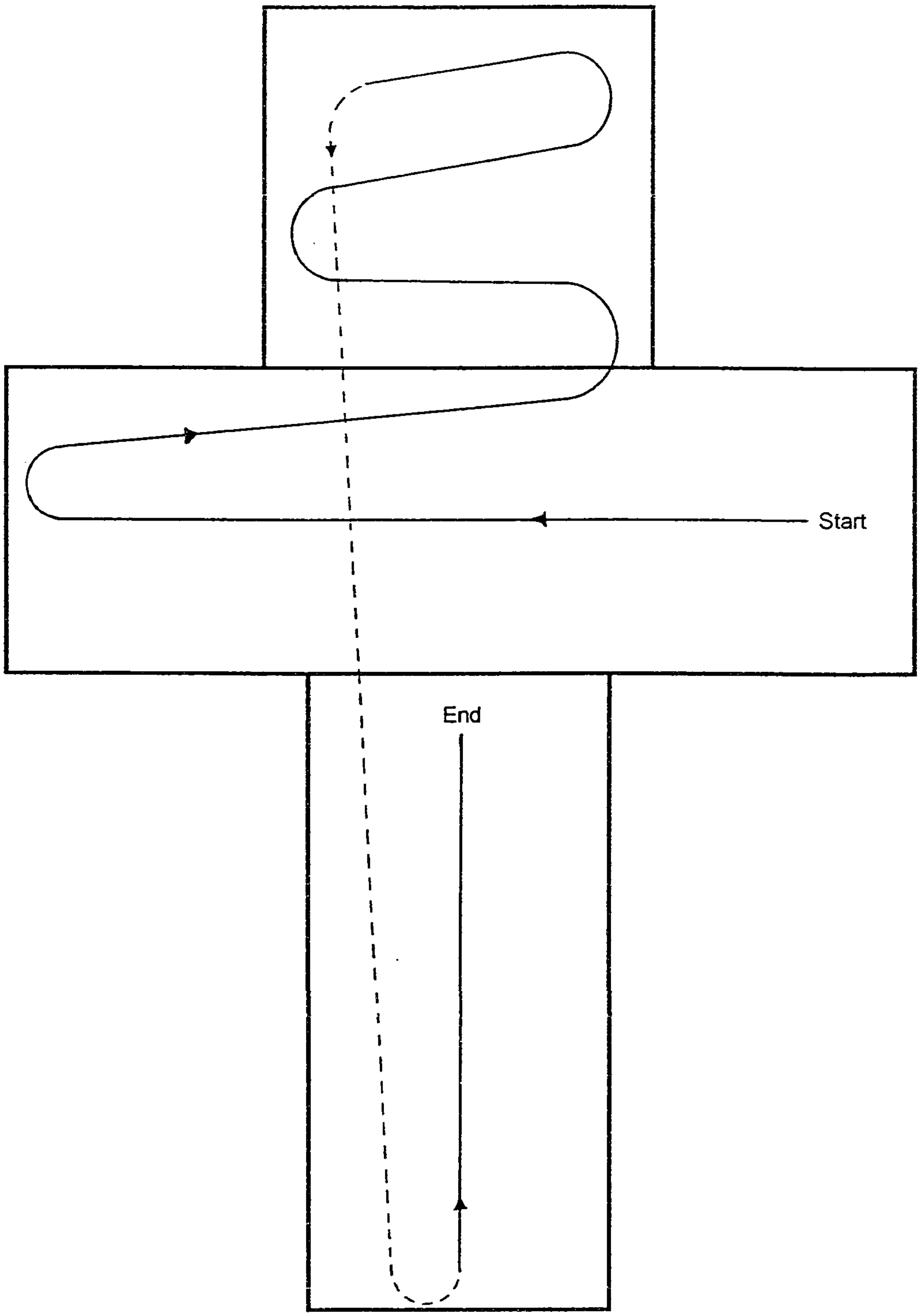

Diagram of the procedure

B727

14 PNEUMATIC BRAKE
HANDLE............................SAFETIED, OFF

13 MACH AIRSPEED WARNING.............TEST
Position TEST switch to No. 1 then to No. 2 and verify that the aural overspeed warning clacker sounds in each position.

4 GND PROX FLAP SYS INHIBIT
SWITCH..................GUARDED, SAFETIED

6 START VALVE ARMING
SWITCH............................GUARDED, OFF

9 WINDOW HEAT SWITCHES................. ON
Verify green ON lights come on.

22 RUDDER TRIM..................................ZERO

21 AUTOPILOT AIL AND ELEV
SWITCHES ....DISENGAGED

12 FIRE WARNING.................................TEST
Hold FIRE TEST switch to ENGS & W.W. (maximum 30 seconds) and observe:
- Wheel well fire warning light come on.
- Engine fire warning lights come on.

5 EMERGENCY EXIT
LIGHTS SWITCH .... GUARDED/ARMED

15 LOW OIL PRESSURE LIGHTS.............. ON

2 FLIGHT CONTROL WARNING
TEST SWITCH............................ TAKEOFF
Verify that warning horn sounds.

8 VOICE RECORDER............................TEST
Push the TEST button momentarily (about 1/2 second). After a short delay, observe two distinct deflections of the monitor meter pointer into the white area.

11 PITOT STATIC HEAT............................. ON
Position PITOT STATIC HEAT switches to ON and observe PITOT OFF light go off.

17 ATTITUDE DIRECTOR
INDICATOR ....TEST
Push the PRESS TO TEST button on the ADI and observe a smooth movement into a climbing right turn indication (approximately 10° pitch up and 20° right roll).

3 MAIN GEAR ANTISKID SWITCH .... OFF
Antiskid INOP lights on.

18 RADIO ALTIMETER............................TEST
Push the TEST button and observe the warning flag appears.

20 FLAPS ....UP
15 Check position indicators and flap handle in agreement.

19 ALTITUDE ALERT .... NO FLAG

B727

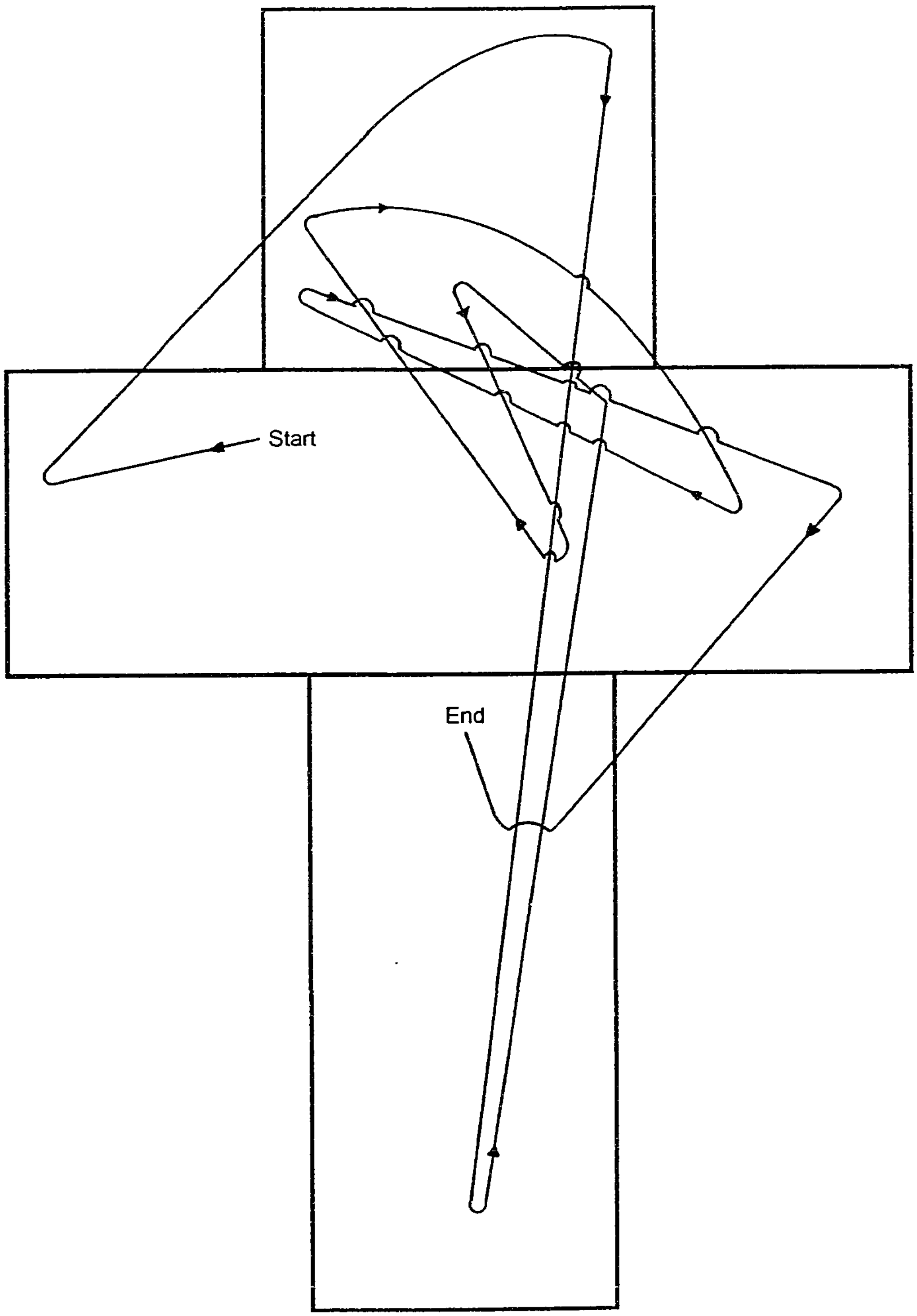

Diagram of the procedure

B757

23 WHEEL WELL FIRE
& DETECTION SYSTEM........................TEST
18 Push the WHL WELL button and observe that the WHL WELL FIRE light comes on.

25 RUDDER TRIM..................................ZERO

22 HSI MODE SELECTOR ....MAP

21 SPEED BRAKE LEVER ....DOWN

16 STANDBY ATTITUDE INDICATOR.....................................CHECK
Verify that there are no flags visible.

17 AUTO BRAKES SELECTOR................RTO

19 ALTN FLAPS KNOB ....NORM
Verify the LE and TE ALTN lights are off.

20 INSTRUMENT SOURCE SELECTIONS...............................NORMAL
Verify the FLT DIR selector is on R, and the FMC, EFI, IRS, and AIR DATA ALTN lights are off.

15 Left and right F/D SWITCHES................ON
14 Ensure both switches off, then position both on.

14 A/T SWITCH..OFF

2 HYDRAULIC PANEL.............................SET
Turn on the right ELEC hydraulic pump (lower right). Observe the associated pressure light go off.

1 IRS MODE SELECTORS ....NAV
Rotate all three IRS selectors to NAV. Observe that all the white ALIGN lights come on after ten seconds.

9 WINDOW HEAT SWITCHES.................ON
Verify amber INOP lights go off.

12 FLT DK, FWD CAB, AFT CAB TEMP CONTROL KNOBS..................AUTO

13 ENGINE BLEED SWITCHES..........CHECK
Verify L and R ENG OFF lights are on.

11 EQUIP COOLING...........................CHECK
Verify amber lights off.

8 RED and WHITE ANTI-COLLISION LIGHTS.....................ON

5 APU ....START
Verify the FAULT light is off. Rotate the APU selector momentarily to START then back to ON.

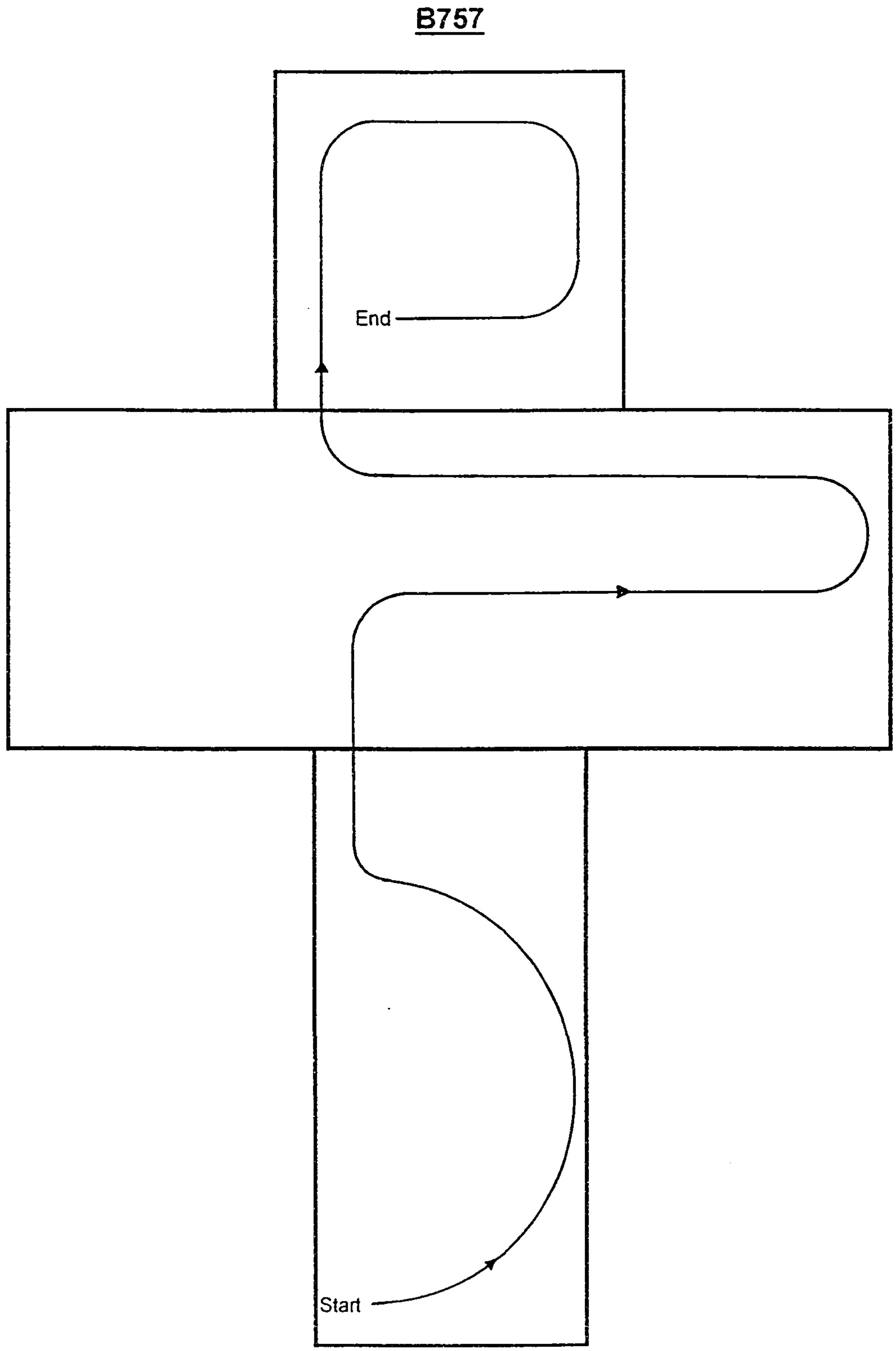

Diagram of the procedure

B757

20 INSTRUMENT SOURCE SELECTIONS.............................. NORMAL
Verify the FLT DIR selector is on R, and the FMC, EFI, IRS, and AIR DATA ALTN lights are off.

1 IRS MODE SELECTORS......................NAV
Rotate all three IRS selectors to NAV. Observe that all the white ALIGN lights come on after ten seconds.

22 HSI MODE SELECTOR .... MAP

9 WINDOW HEAT SWITCHES................. ON
Verify amber INOP lights go off.

2 HYDRAULIC PANEL............................. SET
Turn on the right ELEC hydraulic pump (lower right). Observe the associated pressure light go off.

5 APU .... START
Verify the FAULT light is off. Rotate the APU selector momentarily to START then back to ON.

16 STANDBY ATTITUDE INDICATOR.....................................CHECK
Verify that there are no flags visible.

25 RUDDER TRIM................................. ZERO

11 EQUIP COOLING .... CHECK
Verify amber lights off.

8 RED and WHITE ANTI-COLLISION LIGHTS..................... ON

12 FLT DK, FWD CAB, AFT CAB TEMP CONTROL KNOBS..................AUTO

17 AUTO BRAKES SELECTOR .... RTO

13 ENGINE BLEED SWITCHES .... CHECK
Verify L and R ENG OFF lights are on.

14 A/T SWITCH .... OFF

23 & 18 WHEEL WELL FIRE DETECTION SYSTEM ....TEST
Push the WHL WELL button and observe that the WHL WELL FIRE light comes on.

19 ALTN FLAPS KNOB.........................NORM
Verify the LE and TE ALTN lights are off.

21 SPEED BRAKE LEVER.................... DOWN

15 14 Left and right F/D SWITCHES................ ON
Ensure both switches off, then position both on.

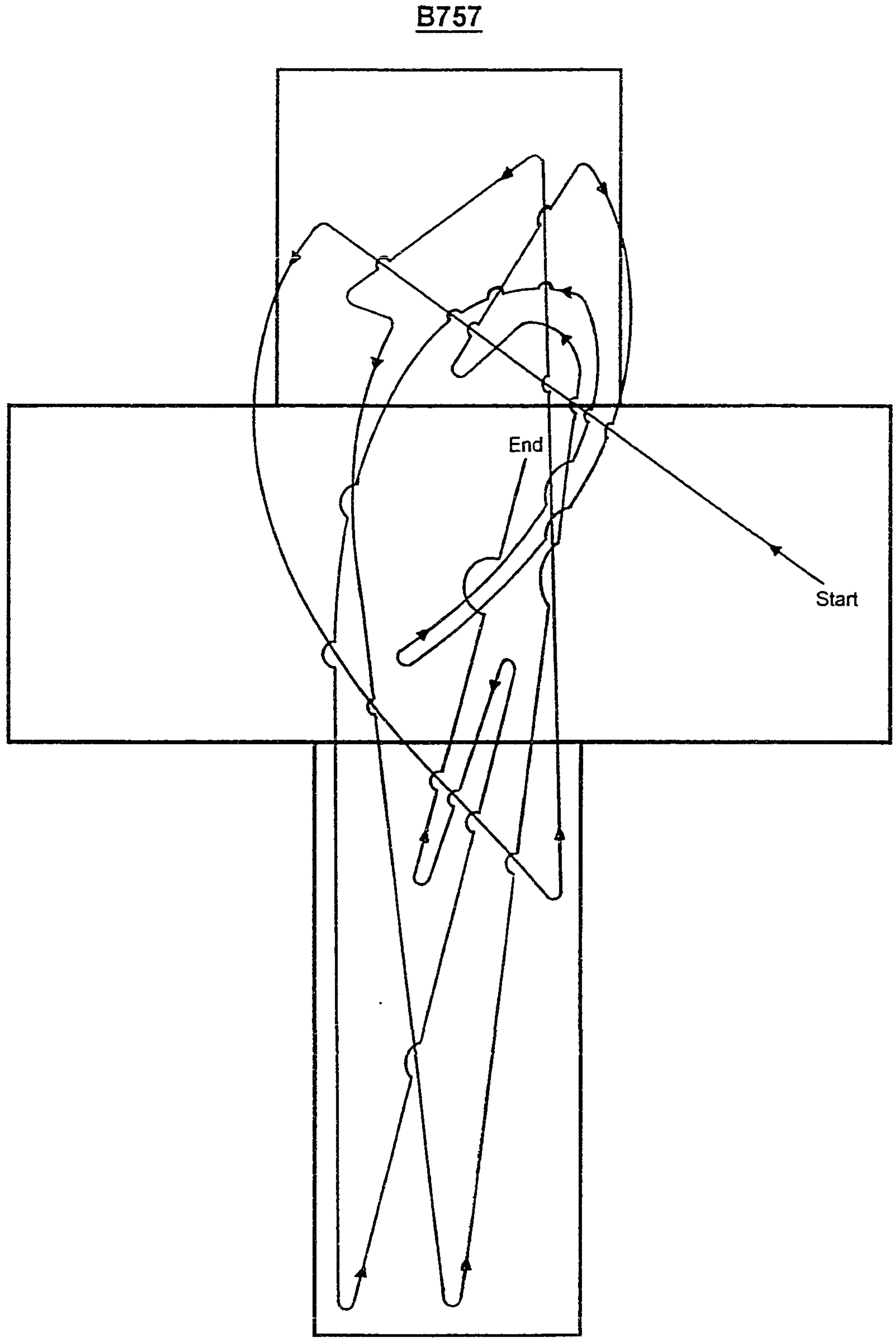

Diagram of the procedure.

DC10

1 ADG SWITCH .... HYD

3 GND PROXIMITY WARN FLAP
OVRD SWITCH .... NORMAL/SAFETIED

5 FUEL VAPOR VENT SWITCHES..........OFF

7 VOICE RECORDER ....TEST
Push the TEST button and observe two distinct deflections of the monitor meter pointer into the white area.

8 WINDSHIELD ANTI-ICE
AND DEFOG ....NORM/ON
Move the L and R ANTI-ICE switches to NORM and move the WINDSHIELD DEFOG switch to ON.

10 ENGINE ANTI-ICE SWITCHES ....OFF
Verify that the ENG & ANT ANTI-ICE switches are all in the OFF position.

6 NO SMOKE/SEAT BELTS SWITCHES.. ON

4 VERT GYRO AND FD CMD
SWITCHES .... NORM
Observe that the AUX DG/VG INOP lights are off.

12 ANNUNCIATOR LIGHTS ....TEST
Push ANNUN LT TEST button and observe all annunciator lights come on.

14 AP SWITCHES .... OFF
Verify that both autopilot switches are off.

13 ATS SWITCHES .... OFF
Verify that both autothrottle switches are off.

15 GROUND PROXIMITY WARNING
SYSTEM ....TEST
Push the GPWS light. Observe the red GPWS and amber FAIL lights come on, and the aural signal sounds ("whoop, whoop, pull up!").

16 GEAR LIGHTS................................ CHECK
Verify 3 green lights are on.

17 CLOCK ....CHECK/SET

18 ATTITUDE DIRECTOR
INDICATOR ....TEST
Push and hold the TEST button on the ADI and observe that the horizon indicates a 20° (±5) right bank and 10° (±5) degree pitch up.

19 TAKEOFF WARNING HORN ....TEST
Move engine 1 or 2 throttle at least halfway forward until the horn sounds. Close the throttle to silence the horn.

21 AILERON TRIM..................................ZERO

20 MARKER SELECTOR SWITCH ....LO

DC10

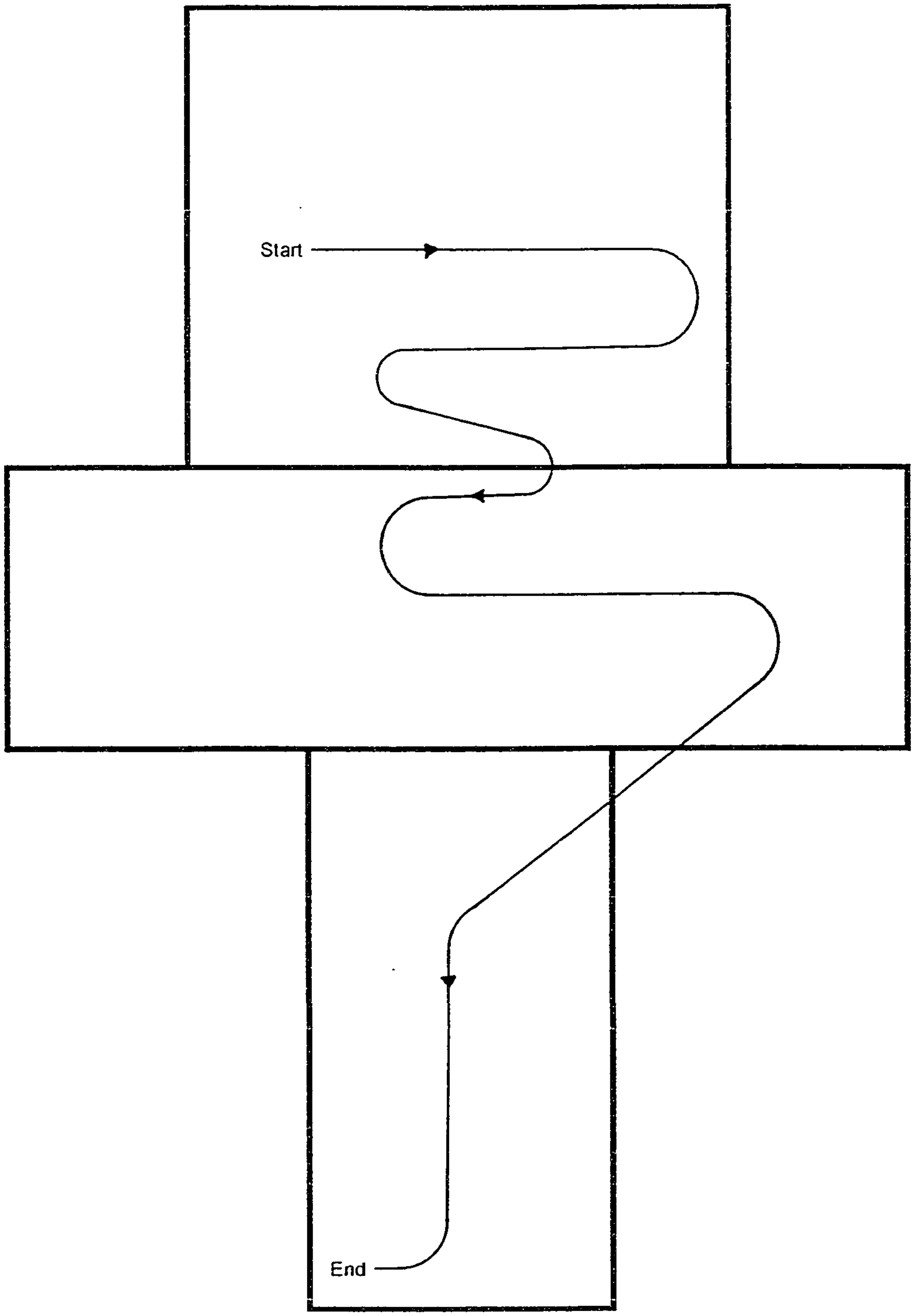

Diagram of the procedure

DC10

4 VERT GYRO AND FD CMD SWITCHES .... NORM
Observe that the AUX DG/VG INOP lights are off.

15 GROUND PROXIMITY WARNING SYSTEM... TEST
Push the GPWS light. Observe the red GPWS and amber FAIL lights come on, and the aural signal sounds ("whoop, whoop, pull up!").

5 FUEL VAPOR VENT SWITCHES.......... OFF

6 NO SMOKE/SEAT BELTS SWITCHES .. ON

20 MARKER SELECTOR SWITCH.............. LO

14 AP SWITCHES..................................... OFF
Verify that both autopilot switches are off.

10 ENGINE ANTI-ICE SWITCHES .... OFF
Verify that the ENG & ANT ANTI-ICE switches are all in the OFF position.

21 AILERON TRIM .... ZERO

1 ADG SWITCH .... HYD

13 ATS SWITCHES................................... OFF
Verify that both autothrottle switches are off.

12 ANNUNCIATOR LIGHTS .... TEST
Push ANNUN LT TEST button and observe all annunciator lights come on.

7 VOICE RECORDER............................. TEST
Push the TEST button and observe two distinct deflections of the monitor meter pointer into the white area.

18 ATTITUDE DIRECTOR INDICATOR .... TEST
Push and hold the TEST button on the ADI and observe that the horizon indicates a 20° (±5) right bank and 10° (±5) degree pitch up.

3 GND PROXIMITY WARN FLAP OVRD SWITCH .... NORMAL/SAFETIED

17 CLOCK .... CHECK/SET

19 TAKEOFF WARNING HORN .... TEST
Move engine 1 or 2 throttle at least halfway forward until the horn sounds. Close the throttle to silence the horn.

8 WINDSHIELD ANTI-ICE AND DEFOG............................... NORM/ON
Move the L and R ANTI-ICE switches to NORM and move the WINDSHIELD DEFOG switch to ON.

16 GEAR LIGHTS................................. CHECK
Verify 3 green lights are on.

DC10

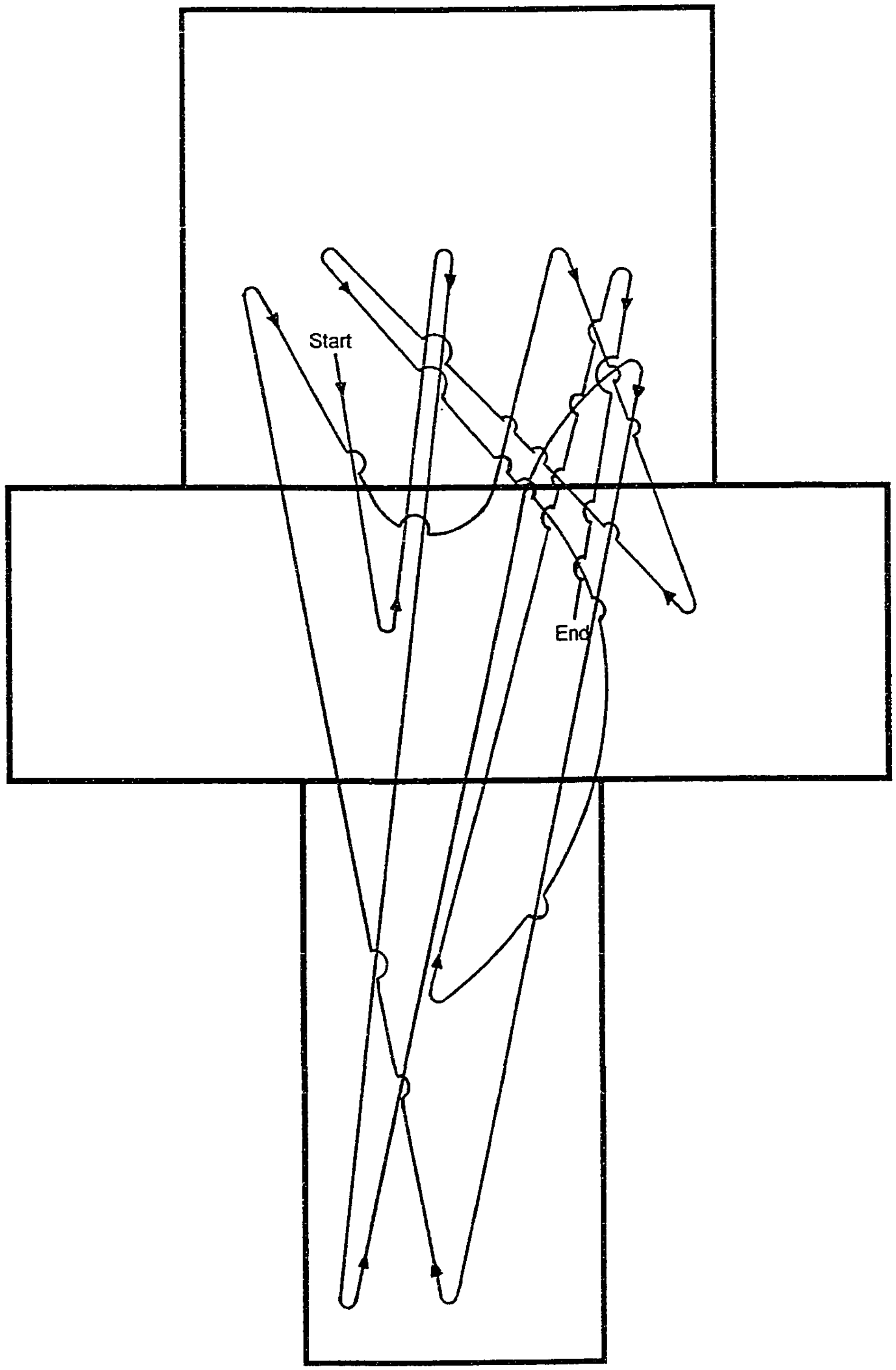

Diagram of the procedure.

Appendix B. Survey Form

Survey

The first page of each procedure you were given was a diagram of the items in the procedure. Was it apparent to you that in each diagram the top box represented the overhead panel, the middle box represented the center instrument panel, and the bottom box represented the pedestal panel?
Y______ N______

Please indicate on the scales how helpful the diagrams were to you in memorizing the procedures.
(sample: |__________↓__________|)

1st procedure: |______________________________|
not helpful — very helpful

2nd procedure: |______________________________|
not helpful — very helpful

3rd procedure: |______________________________|
not helpful — very helpful

4th procedure: |______________________________|
not helpful — very helpful

Please indicate on the scales how frequently you referred to the diagrams.

1st procedure: |______________________________|
not at all — often

2nd procedure: |______________________________|
not at all — often

3rd procedure: |______________________________|
not at all — often

4th procedure: |______________________________|
not at all — often